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Configuration in the Plan View

Vliyaniye Skorosti Postupatel'nogo Peremeshcheniya na
Aerodinamicheskiye Kharakteristiki Apparaton na Vozdushnoy
Podushke Nekrugloy Formy v Plane

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THE EFFECT OF THE TRANSLATIONAL VELOCITY ON THE AERODYNAMIC CHARACTERISTICS OF AIR CUSHION VEHICLES WITH A NONCIRCULAR PLANE CONFIGURATION

L. F. Kalitiyevskiy

The circular plane configuration for air cushion vehicles (ACV) is the optimum one from the viewpoint of lift properties. However, vehicles with an elongated plane configuration are used because of design considerations: rectangular, rectangular with rounded corners, oval, and elliptical.

The method of calculating the aerodynamic characteristics of ACV during translational motion presented in a work [1] can also be used for air cushion vehicles with a noncircular plane configuration.

Experimental pictures of the distribution of pressure over the surface of a solid body with a cross-sectional shape that coincides with the nozzle shape of the ACV are vital for solving the problem.

We shall examine a vehicle with a nozzle that is elliptical in the plane. The aspect ratio of the nozzle, i.e., the ratio of the greater axis of the ellipse to the lesser axis can be arbitrary. In this case the initial tenets and relationships remain the same as for the nozzle that is circular in the plane [1]. It is considered that flow in the jet of the air screen and the incoming flow around the jet are potential. The distribution of pressure along the midline of the jet is assumed to be the same as the distribution of pressure along the surface of a solid elliptical cylinder with potential flow around.

As before, the potential function is given in the form

$$\varphi = \sum_{\substack{m=1 \\ n=0}}^{\infty} a_m^n(r)\, y^m \cos n\Theta - W_0 y. \tag{1}$$

The pressure coefficient is written with the expression

$$\overline{P} = -\frac{2v}{V_\infty}, \tag{2}$$

where v is the low disturbance velocity on the surface of the jet, appearing when the incoming flow flows around it.

The values of pressure coefficients [2] are compared with values of pressure coefficients established on the surface of the elliptical cylinder, which are presented in the form of a series

$$P = \sum_0^k A_k \left(\frac{r}{R}\right)^k \cos k\Theta. \tag{3}$$

Coefficients A_k of the sum [3] are found either according to the experimental data or (lacking such) according to the theoretical distribution of pressure. Coefficients of a series (1) are determined by a system of equations written on the basis of comparing formulas (2) and (3) and the conditions of the value of the vertical velocity component of flow in the jet W (1). One should make changes in the calculation formulas that take into account the difference of shape of the elliptical cylinder from a circular one.

We accept a coordinate system whose origin is at the point of intersection of the axis of an elliptical cylinder with a screen. Axis OY runs along the axis of the cylinder vertically upward, axis OX runs in the velocity direction of the incoming flow, and axis OZ is perpendicular to plane XOY and forms the right-hand coordinate system (translator's note: or frame of axes).

The edges of the nozzle are at a distance h from the ground surface and the plane of the nozzle edge is parallel to the plane of the ground. In the absence of a translational velocity V_∞, we shall have an ellipse in each cross-section height-wise along the jet. The equation of the ellipse can be given as follows:

$$x = a \cos\Theta,$$
$$z = b \sin\Theta, \tag{4}$$

where Θ is an angle with its apex at the coordinate origin, measured from axis OX; a and b are axes of an ellipse and are variable height-wise along the jet.

Let A_0 and B_0 respectively be the major and minor half axes of the base of the nozzle. Assuming that the jet flows normally from the nozzle toward the surface of the ground, one can obtain relationships for the height-wise variable coordinates x and z by analogy with the presentation in work [1]:

$$x = A_0 \left[1 + \frac{h}{A_0} \left(1 - \frac{y}{h} \right) \right] \cos\Theta;$$
$$z = B_0 \left[1 + \frac{h}{B_0} \left(1 - \frac{y}{h} \right) \right] \sin\Theta. \tag{5}$$

Then the value of radii R and r that enter into formulas (1) - (3) are respectively determined by the formulas

$$R = \sqrt{A_0^2 \cos^2\Theta + B_0^2 \sin^2\Theta};$$
$$r = \sqrt{x^2 + z^2}.$$

We calculate the effect of the velocity of the incoming flow on the aerodynamic characteristics of an ellipse with the following characteristics: A_0 = 2500 mm, B_0 = 1250 mm, $\lambda = \frac{A_0}{B_0} = 2$, h = 1000 mm at jet flow velocity W = 60 m/sec

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and a velocity of the incoming flow V_∞ = 20 m/sec.

The distribution of pressure along the surface of the elliptical cylinder is obtained from the formula known from theoretical aerodynamics

$$\widetilde{P} = 1 - \bar{v}_\theta^2. \tag{6}$$

where $\bar{v}_\theta = \dfrac{v_\theta}{V_\infty}$; v_θ - disturbed velocity on the surface of an elliptical cylinder, determined by the expression

$$\bar{v}_\theta = \frac{a+b}{\sqrt{x^2+y^2}}(\sin\theta\cos\beta - \sin\beta\cos\theta). \tag{7}$$

In formula (7), β is the slip angle measured between the major axis of the ellipse and the vector of velocity direction of the incoming flow.

We shall successively examine the cases: β = 0°, β = 90°.

1. The first case corresponds to conventional longitudinal motion of the air cushion vehicle with elongated plane configuration. The picture of flow-around is symmetrical to the greater axis of the ellipse. Having chosen points with an angular position θ = 0, 45, 90, 135, and 180°, as before, and solving the system of ten equations for each cross-section along the height of the jet, we determine coefficients a_{1-10} of the potential function. We calculate deformation of the jet and the distribution of velocities in the jet according to its known values /5 (Figure 1).

2. When β = 90° a jet screen is employed on the wing of the aircraft with nozzle slits parallel to the edges of the wing [2]. The results of the calculation that correspond to this case are given in Figure 2. The system of equations were calculated on the "Promin'" computer during determination of the coefficients.

The investigations showed that the elliptical nozzle plane configuration ensures slight changes of jet screen characteristics in horizontal flight when β = 0. When β = 90°, deformations of the jet screen and the change of flow velocities in the jet are more significant: the relative values of deformations in the corresponding cross-sections are 1.5 - 1.8 times greater and the change of velocity is 1.2 - 1.3 times greater.
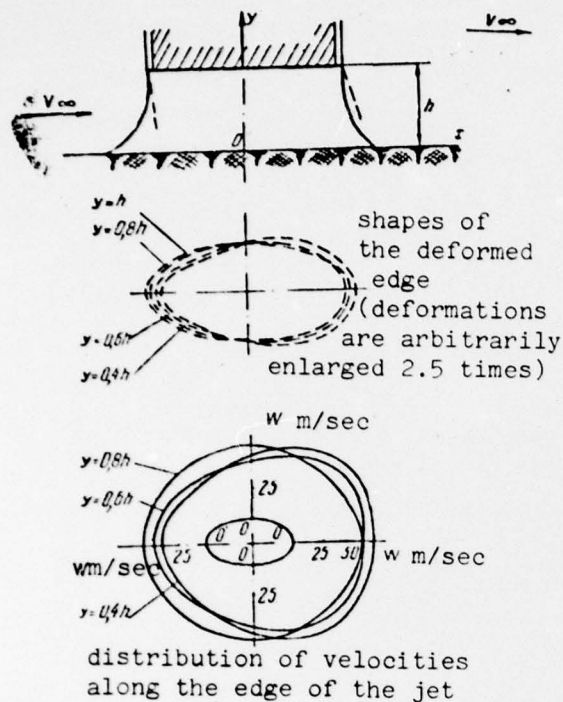
shapes of the deformed edge (deformations are arbitrarily enlarged 2.5 times)

distribution of velocities along the edge of the jet

Figure 1.

shapes of the deformed edge (deformations are arbitrarily enlarged 2.5 times)

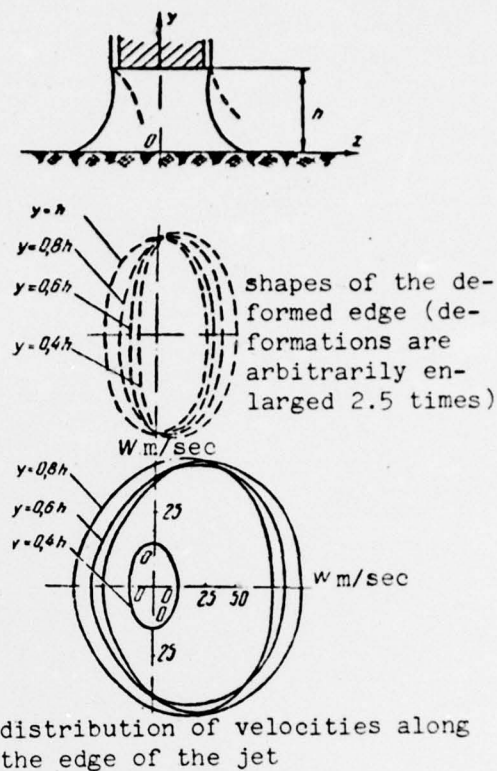distribution of velocities along the edge of the jet

Figure 2.

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